Fault Zone Imaging Using Guided Waves

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RESEARCH OBJECTIVES

The main goal of this project is to develop new seismic image processing technologies. These technologies will improve the quality and resolution of seismic images for complex media, as well as increase our knowledge of the physical processes in rocks.

APPROACH

A significant part of the project involves furthering our understanding of seismic wave propagation in an active fault zone. Our method involves attributing specific features of recorded seismic waves to the structural and physical properties of the fault, which allow extraction of more detailed information from the data. Analysis and interpretation of the data enable extensive numerical modeling of seismic wave propagation in the fault zones. We use microearthquake data from Parkfield, California (located on the San Andreas fault) to apply the new forward modeling techniques we have developed for use on a crustal scale. These techniques are complemented by an innovative guided-wave tomography inversion scheme to obtain high-resolution images of the fault zone core.

Numerical modeling and a number of field observations have indicated the usefulness of propagating fault zone guided waves (FZGW) at Parkfield, which has a 20 to 40% low-velocity fault zone 100 to 200 m wide.

ACCOMPLISHMENTS

Using amplitude guided-wave tomographic inversion, we obtained a unique image (Figure 1) of the inner structure of the San Andreas fault zone, with resolution exceeding travel-time P- and S- wave tomography by a factor of ten. The results show clearly that FZGW are most effectively generated within a well-defined region of the fault zone. This region plunges to the northwest through an area of extremely high seismicity, separating locked and slipping sections of the fault (as determined from both geodesy and microearthquake recurrence rates). We interpret this localized region of FZGW generation to be the northwest edge of the M6 asperity at Parkfield, the low attenuation most likely resulting from dewatering by fracture closure and/or fault-normal compression. Changes in fracture orientation, caused by a complex stress field in the boundary of creeping and locked zones of the fault, are also likely causes of the low attenuation.

SIGNIFICANCE OF FINDINGS

The obtained images indicate a high connectivity between various spatially dependent parameters (such as slip rate, stress change, and wave propagation velocities), which suggests their common origin. This study also shows that FZGW can be used for amplitude tomographic inversion, giving high-resolution, robust images of the narrow low-velocity layers (faults). FZGW-generated images contain several significant features of the fault zone—the region of shallow velocity change in the Vibroseis monitoring, high seismicity, the largest earthquakes and associated high slip rate, the 1966 M6 hypocenter, and the transition from locked to creeping behavior. These results, and specifically the content and quality of the produced images, reinforce the importance of guided waves for fault zone studies.

RELATED PUBLICATION

Korneev, V.A., R.M. Nadeau, and T.V. McEvilly, Seismological studies at Parkfield IX: Fault zone imaging using guided wave attenuation. Bulletin of Seismological Society of America, 2003 (in press).

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, Division of Chemical Sciences, Geosciences, and Biosciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

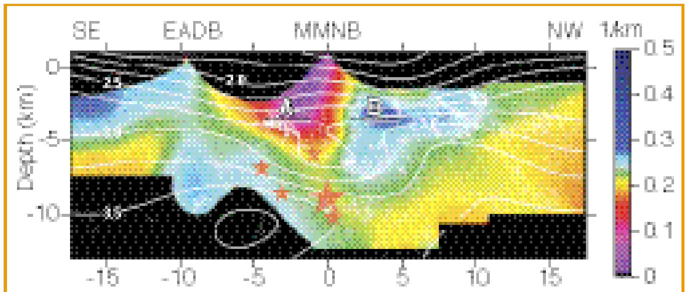

Figure 1. In-fault attenuation-coefficient image of the FZGW tomographic reconstruction, showing the northwest-plunging region of inferred strong fault zone guided-wave generation, Vs contours, 1987–1998 seismicity (small red stars for M>4 events), and the 1966 M6 hypocenter